

WHAT IS CLAIMED IS:

1. A method of device inspection, the method comprising:
providing an asymmetric marker on a device to be inspected, the form of asymmetry of the marker being dependent upon the parameter to be inspected;
directing light at the marker;
obtaining a first measurement of a position of the marker via detection of diffracted light of a particular wavelength or diffraction angle;
obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction angle; and
comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker.
2. A method according to claim 1, wherein the first and second position measurements comprise detection of diffracted light having different diffraction angles but the same wavelength.
3. A method according to claim 1, wherein the first and second position measurements comprise detection of diffracted light having the same diffraction angle but different wavelengths.
4. A method according to claim 1, wherein the first and second position measurements comprise detection of diffracted light having different diffraction angles and different wavelengths.
5. A method according to claim 1, wherein the first and second position measurements are performed simultaneously.
6. A method according to claim 1, wherein the marker comprises one or more diffraction gratings.
7. A method according to claim 6, wherein the one or more diffraction gratings are phase diffraction gratings.

8. A method according to claim 6, wherein the marker comprises a first diffraction grating provided in a first layer of the device, and a second diffraction grating provided in a second layer of the device, the first diffraction grating and the second diffraction grating having a same period and being provided one over the other such that the light is diffracted by both of the diffraction gratings in combination, measured asymmetry between the diffraction gratings indicating overlay of the first and second layers.
9. A method according to claim 8 wherein lines of the first diffraction grating are narrower than lines of the second diffraction grating.
10. A method according to claim 8, wherein the shift is used to determine the overlay of the first and second layers.
11. A method according to claim 10, wherein the overlay is calibrated by using third and fourth diffraction gratings provided in the first and second layers, respectively, the third and fourth diffraction gratings being provided adjacent the first and second diffraction gratings.
12. A method according to claim 11, wherein an overlay offset of a first sign is provided between the first and second diffraction gratings, and an overlay offset of an opposite sign is provided between the third and fourth diffraction gratings.
13. A method according to claim 12, wherein the magnitudes of the offsets are of the order of the largest desired overlay measurement.
14. A method according to claim 13, wherein the offsets are of the order of 100nm.
15. A method according to claim 11, wherein the overlay calibration is used to calibrate overlay measurements obtained using further diffraction gratings at other locations on the device.
16. A method according to claim 11, wherein in addition to the first, second, third and fourth diffraction gratings, fifth and sixth diffraction gratings are provided in the first and second layers respectively, the fifth and sixth diffraction gratings having a different offset to increase the calibration accuracy of the overlay measurement.

17. A method according to claim 11, wherein a further diffraction grating is provided adjacent the other diffraction gratings, either in the first layer or the second layer, the method further comprising measuring the shift for the further diffraction grating to determine a sensor error of the measured shift.

18. A method according to claim 8, wherein the first and second diffraction gratings are provided with a substructure, the substructure of one of the diffraction gratings including a phase jump such that asymmetry arises in the diffracted light as a function of the relative positions of the substructures, the measured asymmetry indicating overlay of the first and second layers.

19. A method according to claim 18, wherein the feature size of the substructure is of the order of a limit of resolution of a lithographic projection apparatus used to project the diffraction gratings onto the device.

20. A method according to claim 18, wherein the feature size of the substructure is sufficiently large relative to the wavelength of the light directed at the diffraction gratings that diffraction from the substructures occurs and propagates between the first layer and the second layer, but the feature size of the substructure is sufficiently small that diffraction from the substructure is not detected during measurement.

21. A method according to claim 18, wherein the first and second diffraction gratings are provided with an overlay offset of a first sign, and third and fourth diffraction gratings having the same substructure are provided, with an overlay offset of an opposite sign, the offsets being used to calibrate the overlay measurement.

22. A method according to claim 21, wherein an additional further diffraction grating is provided adjacent the other diffraction gratings, either in the first layer or the second layer, the method further comprising measuring the shift for the additional diffraction grating to determine a sensor error of the shift.

23. A method according to claim 18, wherein measurements of the substructure are used to reconstruct a substructure shape and thereby relate the shift to overlay.

24. A method according to claim 6, wherein the marker comprises a first diffraction grating provided in a layer of the device, and a second diffraction grating provided in a second layer of the device, the first diffraction grating and the second diffraction grating having different periods each selected to give rise to strong diffraction at different diffraction orders or wavelengths, the asymmetry of the marker being dependent on an overlay of the first and second layers, the measurement comprising measuring the position of the first diffraction grating by measuring one diffraction order or wavelength and measuring the position of the second diffraction grating by measuring the other diffraction order or wavelength, the shift between the measured positions indicating the asymmetry of the marker and the overlay of the first and second layers.
25. A method according to claim 24; wherein the periods of the first and second diffraction gratings are selected such that light diffracted by both diffraction gratings will not yield a strong combined signal having the same frequency as a measured diffraction order.
26. A method according to claim 24, wherein the first and second diffraction gratings are provided one over the other.
27. A method according to claim 24 or claim 25, wherein the first and second diffraction gratings are spatially separated.
28. A method according to claim 27, wherein the first diffraction grating is located adjacent the second diffraction grating as a diffraction grating pair.
29. A method according to claim 28, wherein rotational errors are avoided by providing a second diffraction grating pair, comprising a third diffraction grating having the same period as the; second diffraction grating and a fourth diffraction grating having the same period as the first diffraction grating, the second pair being laterally displaced relative to the first diffraction grating pair, in a direction transverse to lines of the diffraction gratings.
30. A method according to claim 29, wherein one diffraction grating is divided into two rows which lie on either side of the other diffraction grating, the division being along an axis transverse to the direction of lines of the diffraction gratings.

31. A method according to claim 30, wherein both the first diffraction grating and the second diffraction grating are divided into two or more alternating rows.
32. A method according to claim 31, wherein the first diffraction grating and the second diffraction grating have a common axis of symmetry which lies transverse to the direction of lines of the diffraction gratings.
33. A method according to claim 31, wherein the rows are arranged to form a diffraction grating having a period defined by the separation of the rows.
34. A method according to claim 33, wherein the method further comprises monitoring the strength of a beat frequency caused by coupling between light diffracted by the first diffraction grating and light diffracted by the second diffraction grating, to provide an indication of overlay in the direction parallel to the period defined by the separation of the rows.
35. A method according to claim 34, wherein the separation of the rows is selected such that an overlay error arising due to a capture error will give rise to strong coupling.
36. A method according to any of claims 30, wherein an offset is introduced into one of the diffraction gratings relative to the other diffraction grating, the size of the offset being selected to minimize coupling between light diffracted by the first diffraction grating and light diffracted by the second diffraction grating.
37. A method according to claim 24, wherein the method further comprises determining sensor error by providing in the first layer of the device a third diffraction grating having the same period as the second diffraction grating, and providing in the second layer of the device a fourth diffraction grating having the same period as the first diffraction grating, the sensor error being eliminated by comparing the measured shift for the first and second diffraction gratings and the third and fourth diffraction gratings.
38. A method according to claim 6, wherein the marker comprises a diffraction grating arranged to measure the focus accuracy of a lithographic projection apparatus, the method

comprising providing on a mask of the lithographic projection apparatus a diffraction grating having a substructure which includes a step in optical path length, the step being of opposite sign for adjacent lines of the diffraction grating, the step being selected such that during projection by the lithographic projection apparatus of the diffraction grating onto the device, a focus error will cause the projected diffraction grating to be displaced, adjacent lines of the projected diffraction grating being displaced in opposite directions, giving rise to an asymmetry which is measured by the shift.

39. A method according to claim 38, wherein the step in optical path length is such that it introduces a phase difference of substantially one quarter of the wavelength of light used to project the diffraction grating onto the device.

40. A method according to claim 38, wherein the relative widths of the adjacent lines of the diffraction grating are selected to be different such that the asymmetry of the projected diffraction grating is sufficiently large to be measured by the shift.

41. A method according to claim 6, wherein the marker comprises a diffraction grating arranged to measure a critical dimension of a lithographic projection apparatus, the method comprising providing on the device a diffraction grating having a substructure with a period at, or of the order of, the limit of resolution of the lithographic projection apparatus, the substructure being arranged to extend lines of the diffraction grating thereby rendering the diffraction grating asymmetric, changes of the critical dimension modifying the effective reflectivity of the substructure thereby modifying the asymmetry of the diffraction grating, the modified asymmetry being measured by the shift.

42. A method according to claim 6, wherein the marker comprises a first diffraction grating and an adjacent second diffraction grating, the first diffraction grating and the second diffraction grating having different periods each selected to give rise to strong diffraction at different diffraction orders, such that a measurement of the position of the first diffraction grating is provided by measuring one diffraction order and a measurement of the position of the second diffraction grating is provided by measuring the other diffraction order, the method comprising processing the first and second diffraction gratings so that the marker includes an asymmetry arising from processing effects, and measuring the shift between the first and second positions to determine the effect of processing on the marker.

43. A method according to claim 42, wherein the processing effect is quantified by comparison of the shift with previously measured shifts determined for known processing asymmetries.
44. A method according to claim 42, wherein the processing is cleared from the second diffraction grating prior to measurement of the positions of the first and second diffraction gratings.
45. A method according to claim 44, wherein the marker further comprises a third diffraction grating and a fourth diffraction grating having periods which correspond to the first and second diffraction gratings respectively, the method further comprising processing the third and fourth diffraction gratings and clearing processing from them, measuring the positions of the third and fourth diffraction gratings to determine the shift between the measured positions. And using the determined shift to correct errors in a shift measured for the first and second diffraction gratings.
46. A method according to any of claims 24, wherein the first and second diffraction gratings are used to measure processing asymmetry using the method according to claim 42.
47. A method according to claim 24, wherein prior to the overlay measurement the first diffraction grating is used to determine an aligned position for projection onto the device of an image including the second diffraction grating.
48. A method according to claim 47, wherein following the overlay measurement the second diffraction grating is used to determine an aligned position for projection onto the device of a subsequent image.
49. A method according to claim 47, wherein the projected image includes an additional diffraction grating having a different period from the second diffraction grating, the method further comprising using the additional diffraction grating to determine an aligned position for projection onto the device of a subsequent image.
50. A method according to claim 1, wherein the inspection method is performed directly after exposure of the marker on the device.

51. A method according to claim 1, wherein the inspection method is performed after exposure and post exposure bake of the marker on the device.
52. A method according to claim 1, wherein the inspection method is performed after exposure and hard bake of the marker on the device.
53. A method according to claim 1, wherein the inspection method is performed after exposure and processing of the marker on the device.
54. A method according to claim 1, wherein the inspection method is performed after application of a layer of resist onto the device and before exposure of that resist, the marker being provided in one or more processed layers of the device.
55. A method according to claim 1, wherein the method is performed for a device located within a lithographic projection apparatus, the position of the marker being used to provide alignment information for lithographic projection in addition to providing inspection of the device.
56. A device inspection apparatus, the apparatus comprising:
a light source arranged to direct light at an asymmetric marker provided on a device;
a detector arranged to detect light diffracted from the marker with a particular wavelength or diffraction angle thereby providing a measurement of the position of the marker,
a second detector arranged to detect light diffracted from the marker with a different wavelength or angle order thereby providing a second measurement of the position of the marker; and
a metrology unit configured to compare the measured positions to determine a shift indicative of the degree of asymmetry of the marker.
57. A device inspection apparatus according to claim 56, wherein the apparatus is located within a lithographic projection apparatus.

58. A device inspection apparatus according to claim 56, wherein the apparatus is located within a track connected to a projection apparatus.
59. A device inspection apparatus according to claim 56, wherein the apparatus is provided in a housing which is separated from the lithographic projection apparatus.
60. A device inspection apparatus including a light source arranged to direct light at an asymmetric marker provided on a device; a detector arranged to detect light diffracted from the marker with a particular wavelength or diffraction angle thereby providing a measurement of the position of the marker, a second detector arranged to detect light diffracted from the marker with a different wavelength or angle order thereby providing a second measurement of the position of the marker; and a metrology unit configured to compare the measured positions to determine a shift indicative of the degree of asymmetry of the marker, wherein the apparatus is configured to perform the method according to claim 1.
61. A device inspection apparatus, the apparatus comprising a light source arranged to direct light at a phase diffraction grating provided on a device, a detector arranged to detect light diffracted from the phase diffraction grating, and a metrology unit configured to obtain inspection information using the detected diffracted light.
62. A metrology unit, comprising:
a broadband light source configured to direct light at a marker on a device to be inspected;
a translatable carrier bearing at least one reference grating;
a spectrometer diffraction grating configured to separate the light into different wavelengths; and
a detector array arranged to detect the light at different wavelengths, the metrology unit being configured such that in use light diffracted by the marker on the device passes through the at least one reference grating and via the spectrometer diffraction grating to the detector array, the reference grating being translated such that a periodic signal is detected at the detector array.
63. A metrology unit according to claim 62, wherein the metrology unit further comprises a reflectometer configured to detect light which is retro-reflected from the marker.

64. A method of device inspection, the method comprising:
 providing on a device to be inspected an asymmetric marker comprising a first diffraction grating in a first layer of the device, and a second diffraction grating in a second layer of the device, the first diffraction grating and the second diffraction grating having the same period and being provided one over the other such that the light is diffracted by both of the diffraction gratings in combination, the asymmetry of the marker being dependent upon the overlay of the first and second layers;

directing light at the marker, obtaining a first measurement of the position of the marker via detection of diffracted light of a particular wavelength or diffraction angle;

obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction angle; and

comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker.

65. A method of device inspection, the method comprising:

providing on a device to be inspected an asymmetric marker comprising a first diffraction grating in a first layer of the device, and a second diffraction grating in a second layer of the device, the first diffraction grating and the second diffraction grating having different periods each selected to give rise to strong diffraction at different diffraction orders or at different wavelengths, the asymmetry of the marker being dependant on an overlay of the first and second layers;

directing light at the marker;

obtaining a first measurement of the position of the marker via detection of diffracted light of a particular wavelength or diffraction order;

obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction order; and

comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker and the overlay of the first and second layers.

66. A method of device inspection to measure the focus accuracy of a lithographic projection apparatus, the method comprising:

providing on a mask of the lithographic projection apparatus a diffraction grating having a substructure which includes a step in optical path length, the step being of opposite sign for adjacent lines of the diffraction grating;

using the lithographic projection apparatus to project the diffraction grating onto the device, adjacent lines of the projected diffraction grating being displaced in opposite directions to form an asymmetric marker due to the step;

obtaining a first measurement of the position of the marker via detection of diffracted light of a particular wavelength or diffraction angle;

obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction angle; and

comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker and of the focus error.

67. A method of device inspection to measure a critical dimension of a lithographic projection apparatus, the method comprising:

providing on a device to be inspected an asymmetric marker comprising a diffraction grating having a substructure with a period at, or of the order of, the limit of resolution of the lithographic projection apparatus, the substructure being arranged to extend lines of the diffraction grating thereby rendering the diffraction grating asymmetric, changes of the critical dimension modifying the effective reflectivity of the substructure thereby modifying the asymmetry of the diffraction grating;

directing light at the marker;

obtaining a first measurement of the position of the marker via detection of diffracted light of a particular wavelength or diffraction angle;

obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction angle; and

comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker and of the critical dimension of the lithographic projection apparatus.

68. A method of device inspection, the method comprising:

providing on a device to be inspected an asymmetric marker comprising a first diffraction grating in a first layer of the device, and a second diffraction grating in a second layer of the device, the first diffraction grating and the second diffraction grating having

different periods each selected to give rise to strong diffraction at different diffraction orders or at different wavelengths, the asymmetry of the marker being dependant on the overlay of the first and second layers;

processing the first and second diffraction gratings so that the marker includes an asymmetry arising from processing effects;

directing light at the marker, obtaining a first measurement of the position of the marker via detection of diffracted light of a particular wavelength or diffraction order;

obtaining a second measurement of the position of the marker via detection of diffracted light of a different wavelength or diffraction order, and

comparing the first and second measured positions to determine a shift indicative of the degree of asymmetry of the marker and the effect of processing on the marker.